# PATENT SPECIFICATION

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## (54) FASTENER FOR MULTI METAL STACKS

(71) I, LARRY SALTER, a citizen of the United States of America, residing at 5655 Dunrobin Avenue, City of Lakewood, State of California, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to fasteners and particularly precision type fasteners for aircraft use.

Sundry expedients utilizing straight and tapered shank fasteners have been heretofore restored to with varying degrees of success, for the purpose of fastening together multiple sheets of metal in fatigue critical aircraft structure.

Even though the exact dimensions may be specified for the individual fastener and hole and held within the tightest tolerances listed in current specifications, the benefits anticipated are often lost in the accumulative tolerances inherent to the most sophisticated piece by piece assembly systems. The fasteners used in the wet wing design of today's aircraft are possible sources of fuel leakage and are usually reinforced by additional additive sealant measures. In a wet wing there is no separate tank for fuel. It is therefore undesirable in what the industry terms an interference fastener fit system to have any inherent clearances which are subject to accumulating.

The problem cannot be solved by providing unlimited amount of interference fit in most aircraft applications without exceeding interference design maximum limits necessary to permit reasonable installation forces and avoid stress corrosion cracking where applicable.

Where, for example, a sleeve is secured in a hole, the term interference has been chosen to mean that the sleeve has been expanded to an outside diameter greater than the initial diameter of the hole thereby to force the metal forming the hole laterally outwardly and thereby anchor the sleeve in the hole. The term interference fit naturally applies also to bolts, nuts and other assemblies where a comparable action takes place.

In supplying precision type fasteners of the sort made reference to, some prior structures have restored to making use of a tapered bore through the multiple layers for reception of the tapered shank of a bolt or rivet.

Although such structures have been widely used in the past and have been acceptable as providing a dependable fastening system in aircraft the cost of a tapered hole type fastener in today's titanium-aluminium aircraft prohibits its consideration for use in many applications. Such holes can only be drilled by specially constructed drills requiring several subsequent reaming operations to achieve the required fastener-to-hole bearing requirements. When fasteners are replaced or holes re-drilled for oversize fasteners a whole new series of oversize bolts, drills, reamers and gauges are necessary. Oversize bolts are more costly and curtail the aircraft performance by adding considerable weight when used in large quantities.

When for example, a fastener must be replaced the hole is made bigger. This requires a larger fastener and since the bolt is a solid piece of material it weighs more than the smaller original bolt and the entire joint is then correspondingly heavier.

In recognizing the possible advantages of employing a cylindrical bore in the multiple layers, the prior art has made use of a sleeve of cylindrical form on the exterior and having a tapered passage through it. Such fasteners as have followed this principle have been such as to necessitate application of the fastener parts from opposite sides of the multi-layer stack and hence have presented installation problems. Other inherent weaknesses exist at the head of the bolt or fastener where rupture under vibration stress is most prevalent. Also piece by pieve installation

of the fastener parts tends to increase the undesired accummulation of tolerances.

It is commonly understood and appreciated that even when multiple layers of metallic material have a straight bore drilled through them, the bore will not always be perfectly concentric throughout its length, also because some metallic layers may be of different kinds of metal with different degrees of hardness, a drilled straight or tapered hole may readily not be consistent throughout its length, within acceptable tolerances.

One cause of the difference is the fact that the cutting tool cuts differently as it passes through the various layers of different metal such as titanium and aluminium. A difference of .002" is common for a stack of titanium and aluminium. It is also the fact that thickness of the metallic layers may vary slightly, some being thicker than normal and others thinner than normal and hence the length of the bore through the multiple layers will not be exactly the same on all occasions.

Since fasteners of the type here under consideration depend upon an interference fit, in other words expansion laterally into engagement with the wall of the bore, the expansion is controlled in the finished joint to provide interference levels within tight limits irrespective of variations in the materials used and dimensional tolerances of both the bore and the fastener.

According to this invention in its broadest aspect a fastener for making a joint with multiple layers of material having a cylindrical hole there-through comprises a shaft having a tapered shank and a hollow cylindrical sleeve of generally constant outside diameter but internally having the same taper as said shank, the maximum internal diameter of the sleeve being less than the maximum diameter of the shank, a portion of said sleeve being arranged to accept and be expanded by an initially inserted portion of the tapered shank such that a remaining portion of the shaft lies within but not contacting a remaining portion of the sleeve, said remaining portion of the sleeve having a wall thickness which is reduced to compensate for expansion of said remaining portion of the sleeve when the shank is fully inserted into the sleeve so that the exterior surface of the sleeve then has a constant outside diameter.

According to one aspect of this invention a two piece high strength fastener consists of a partially assembled tapered shaft and internally tapered hollow cylindrical sleeve, the shaft having a tapered shank with a maximum diameter at one end, the hollow cylindrical sleeve having a given outside diameter and a tapered inside diameter defining a maximum diameter at one end that is less than the maximum diameter on said tapered shank, said taper on the said shank being substantially equal to said taper on said sleeve, the sleeve being initially inserted over the tapered shank and positioned at a given distance from said maximum diameter end of the shank with that portion of sleeve contacting said tapered shank being radially expanded, and the outside diameter of the expanded sleeve having been reduced to a given cylindrical dimension, the improvement comprising reducing the wall thickness of that portion of the sleeve remaining un-contacted by the initially inserted shank to compensate for expansion of said remaining portion of the sleeve when the shank is fully inserted into the sleeve so that the exterior surface of the sleeve then has a constant outside diameter.

In one embodiment of the invention the external diameter of said sleeve not contacted by said initially inserted shank is taperingly reduced to provide the necessary compensation when expanded although alternatively the internal diameter of the portion of said sleeve not contacted by said shaft is increased in diameter by a taper of reverse direction to the taper on the shank to provide the necessary compensation when expanded.

Preferably the taper of the shank and the sleeve is between 0.15 inch and 0.5 inch per foot. Advantageously there is provided a head defining a shoulder formed to said tapered shank by an annular fillet portion.

In accordance with a further aspect of this invention there is provided a two piece high strength fastener consisting of a partially assembled shaft and internally tapered hollow cylindrical sleeve, the shaft having a tapered shank with a maximum diameter at one end, the hollow cylindrical sleeve having a given outside diameter and a tapered inside diameter defining a maximum diameter at one end that is less than the maximum diameter on said tapered shank, said taper on said shank being substantially equal to said taper on said sleeve, the sleeve being inserted over the tapered shank and positioned at a given distance from said maximum diameter end of the shank to radially expand that portion of sleeve contacting the shaft, the method compensating for the unexpanded portion of the sleeve comprising the steps of reducing the outside diameter of the expanded sleeve to a given cylindrical dimension, and further reducing the wall thickness to compensate for expansion of said portion of sleeve not contacted by the shaft in said partial assembly when the shaft is fully inserted into the sleeve so that the sleeve then has a constant outside diameter.

Preferably reduction in thickness is performed by reducing the external

diameter of the portion of tapered sleeve not contacted by said shaft to provide the necessary compensation when expanded, or, in an alternative method, by increasing the internal diameter of the portion of said tapered sleeve not contacted by said shaft to provide the necessary compensation when expanded.

The invention consists of the construction, arrangement, and combination of the various parts of the device, as hereinafter set forth, pointed out in the apended claims and illustrated in the accompanying drawings, in which:

Figure 1 is an exploded view partially broken away showing one form of the sub-assembly parts as they would be shipped;

Figure 2 is a longitudinal sectional view showing the fastener parts of Figure 1 in place in a multi-metal stack;

Figure 3 is a fragmentary sectional view on the circular line 3 of Figure 2;

Figure 4 is a longitudinal sectional view of the form of device of Figure 1;

Figure 5 is a fragmentary sectional view on the circular line 5 of Figure 4;

Figure 6 is a longitudinal sectional view of the fastener applied to an irregular hole prior to tightening;

Figure 7 is a longitudinal sectional view similar to Figure 6 of the fastener on completion of the installation;

Figure 8 is a longitudinal sectional view of the fastener of the type of Figure 6 wherein the material of the fastener sleeve is harder than the material of the stack;

Figure 9 is a longitudinal sectional view similar to Figure 8 but on completion of the installation;

Figure 10 is a longitudinal sectional view similar to Figure 8 but wherein the metals of the stack are of different kinds and degrees of hardness, showing the joint made up;

Figure 11 is a longitudinal sectional view of a sub-assembly of another form of the fastener;

Figure 12 is a longitudinal sectional view of the sub-assembly of Figure 11 in initially inserted position in holes through a metal stack;

Figure 13 is a longitudinal sectional view similar to Figure 12 showing the completed installation in the stack;

Figure 14 is a longitudinal sectional view of a sub-assembly using another form of sleeve;

Figure 15 is a longitudinal sectional view showing initial installation of the sub-assembly of Figure 14;

Figure 16 is a view similar to Figure 15 but showing the final assembly completely installed;

Figures 17 and 18 are longitudinal sectional views of a sub-assembly in general like that of Figures 1 to 4 showing an expedient for adjusting the initial outside diameter size of the sleeve;

Figure 19 shows a fragmentary longitudinal sectional view of a sub-assembly comparable to Figures 1 to 4.

In one embodiment of the invention as shown in Figure 1 which has been chosen for the purpose of illustration, a pre-assembly or sub-assembly 10 of fastener parts consists of a bolt 11 and sleeve 12. When the pre-assembly is ultimately installed, a nut 13 is adapted to be applied to the bolt over a washer 14.

The sleeve 12 is of a construction consisting as shown of a cylindrical exterior surface 15 and a tapered passage 16 on the inside. The tapered passage provides a relatively thick wall 17 at one end of the sleeve and a relatively thin wall 18 at the opposite end. The end at the thick wall is shown squared off and the end at the thin wall is provided with an internal flare or bevel 19. Proportions are exaggerated for the purpose of illustration.

The bolt 11 consists of a head 20, a shaft 21, and a threaded end 22. There is a taper throughout the length of the shaft which is the same taper, in other words which has the same angular departure from the axis, as does the passage 16 through the sleeve. The taper may have a valve in the range 0.15 inch to 0.5 inch per foot. There is, however, a significant difference between the bolt and the sleeve in that the average or mean diameter of the bolt is larger than the average or mean diameter of the sleeve.

What is significant is to make sure that when all tolerances accumulate adversely in one direction the desired interference will still be assured.

What makes the device of the invention unique and already in great demand is its ability to make dimensional deviations on the individual components within the assembly of little or no consequence once the fastener is in place.

It is also of consequence that there be provided a fillet 26 between the annular surface 24 of the bolt head 20 and the circumference of the shaft 21. It has been established that this location is one most subject to fatigue in devices experiencing vibration conditions of fasteners of this kind and that it is important to provide such a fillet as reinforcement to make the fastener uniformly resistant to fatigue at all locations. The fillet additionally serves to form the flange on the sleeve as shown in Figures 3 and 5 and to cold work the base of the countersink shown in Figures 15, 16, and 18.

When the fastener of Figure 1 is to be installed in a hole or bore 30 which extends through four layers 31, 32, 33, and 34 of

metal sheets, the sub-assembly of Figures 1 is inserted from the face 35 of the stack. Clearance between the cylindrical exterior surface 15 and the sleeve 12 is exaggerated in Figure 2 but it should be kept in mind that the clearance required to enable the sub-assembly to be readily slid into the bore is a clearance of about .001 inch. Since the dimensional tolerance of the bore is normally about .002 inch the aggregate clearance which is likely to be encountered under the condition of greatest tolerance is about .003 inch per inch of diameter.

Different expedients may be employed to expand the sleeve enough to have it frictionally engage the wall of the hole until the interfering expansion can be started. When there is a wrench hold on the head as in Figures 1 and 4 the head can be held non-rotatable while the nut 13 is threadedly engaged against the washer and the sleeve, drawing the tapered bolt into the sleeve to expand the sleeve.

When there is no wrench hold on the head the head can be tapped with a bucking bar to expand the sleeve.

There are, however, occasions when the partly expanded outside diameter of the sleeve is too large for the hole in which it is to be inserted. The diameter can be reduced by withdrawing the bolt from the sleeve for a limited distance. When this is done the energy stored in the sleeve will cause it to retract.

Figures 17 and 18 show a way in which the bolt can be withdrawn. In this arrangement a washer 27 is supplied at a location between the head 20' of the bolt and the thin end 18 of the sleeve. To push the sleeve outwardly away from the head 20' a tool 28 having a skirt 28' and a pocket 29 is employed. The edge of the skirt 28' is pressed or driven by impact against the washer 27 in the direction of the arrows as shown in Figure 18. The effect of this action is to drive the sleeve downwardly as shown in Figure 21, withdrawing it from the shaft 21 a short distance. The sleeve, previously expanded, then contracts and the diameter of the exterior surface becomes smaller.

Figure 19 explains in specific detail how the sleeve can be made smaller by a predetermined measured amount in precision type fasteners of the type here under consideration.

For the purpose of illustration only without any limitation intended on the use of methods, rate of taper or dimensions utilized in the invention described, the working principle and a means of attainment illustrated in Figure 19 are further described as follows.

The relationship of diametric expansion (D-DIA) to a reduction in the dimension P which is the required position of the sleeve from the bearing surface of the head is achieved by making the tapered sleeve bore smaller in average diameter than the average diameter of the fastener shaft.

The amount equal to that necessary to provide maximum contact between the shaft and bore is determined by totalling the dimensional tolerances permitted during the manufacture of the sleeve fastener, and application of fastener coating and lubricant.

Taking as an example a taper of 0.25 inch/ft, the numerical taper value is 12/0.25 = 48 and the amount of potential clearance or deviation established is converted to thousandths of inches in this example by use of the D = P/48 relationship. The dimensional value must be added to the P dimension where it will be represented as that portion of the 1P dimension greater than P.

After insertion of the fastener shaft by hand pressure into the tapered bore, the 1P dimension which the sub-assembly position of the sleeve relative to the head prior to insertion and machining, is verified to be within the limits specified for the particular assembly.

The fastener shaft is now driven to a location between the middle to upper limit of the specified P dimension, expanding D just beyond the amount required. At this point of assembly manufacture the sleeve is machined to final diameter D while the sleeve 12 remains on the shaft 21 within tight limits.

In this invention a small portion of the sleeve is not in contact with the fastener shaft during final machining, so that a compensating deviation traced from the proportionate longer portion of shaft engaged is produced on the portion of the sleeve not expanded at this point. This operation brings the entire D dimension within the proper limits throughout its length, upon final assembly in the aircraft.

In the preferred form of the invention the D dimension is held within .001 inch or less in the majority of applications.

In order to provide compensation in that portion of the sleeve that has not been expanded by the insertion of the tapered shank, i.e. that portion of the sleeve which is not contacted by the shank, the wall of the said portion is reduced in thickness by the use of a taper on either the outside diameter or inside diameter of the sleeve which taper has the same taper as that taper on the shank. In the final assembly, insertion of the shank will expand the lower most portion of the sleeve in amounts equal to the compensation by which the lower most portion of the sleeve has been reduced in thickness. In the particular embodiment

of the invention where the inside diameter of that portion of the sleeve that has not been expanded by the portion of the tapered shank is increased in diameter it is tapered in a direction that is equal and opposite to the taper on the shank. Reducing the thickness of that portion of the sleeve which has not been previously expanded produces the basis for the compensation which brings the entire external dimension within the proper limits throughout its length upon final assembly in the aircraft.

An illustrative example of the unique advantage of the present invention is that for a 3/4" sleeve assembly a sleeve expansion can be assured, to a prospective user, falling in a narrow range of between .006 and .010 inch even in instances where the user's hole clearance is initially between 0.0 and .0025.

The assembly as just described is ready at this point for shipment to the user and carries a guaranteed expansion rate proportionate to the further insertion of the fastener shaft during assembly in place.

In the form of the device of Figures 1 to 4 for example, the washer 14 overlies the squared off end of the sleeve as shown in Figure 2 preventing the sleeve from shifting while the shaft 21 is forced into the passage 16 progressively spreading all portions of the sleeve uniformly outwardly into engagement with the wall of the bore 30, whereby to exert pressure against the material of the sheets 31, 32, 33 and 34 in the example shown.

The spreading of the sleeve 12 may be calculated for all circumstances as sufficient to generate pressure outwardly in the material of the sheets in a range between about that approaching the elastic limit and rupture point. Various conditions and circumstances, however, may be such as to suggest an adequate pressure as being less than the elastic limit of the material surrounding the bore.

With the washer 14 in place against the end of the sleeve, as this spreading takes place the bevel 19 of the sleeve will be forced around the fillet 26 of the bolt to the position shown in Figures 4 and 5. Compressed as shown, the small end of the sleeve flares outwardly and culminates ultimately in a point 18'.

After the bolt 11 and sleeve 12 have been fully expanded into the bore 30, the washer 14 can be removed after temporary removal of the nut 13 and the nut then tightened into the position shown in Figure 4 against a face 36 of the stack. The installation made reference to assumes full thickness of all of the layers 31, 32, 33, and 34 and that the length of the sleeve will be more or less the same as the total aggregate thickness of the layers.

Occasions do occur when the aggregate thickness of the layers 31, 32, 33, and 34 is on the thin side which would make the sleeve measurably longer than the full length of the bore 30. Under such circumstances, a counter bore nut or washer to be described later would accommodate the adjacent protruding end of the sleeve allowing it to bear against the bottom of the clearance before expanding the sleeve by the action heretofore described.

In the installation shown in Figures 6 and 7 the same fastener is shown applied to sheets 31, 32, 33, and 34 wherein a bore 40 through the sheets 31, 32, 33, and 34 is of irregular shape and diameter due to various reasons which might be either faulty drilling or an improperly dimensioned drill bit, or some other reason which would result in an irregular bore. Under the circumstances, it could conceivably occur in drilling a bore through metal sheets such as aluminium. Under such circumstances, especially where the sleeve 12 is of relatively soft material, the cylindrical exterior surface 15 of the sleeve will be distorted and the sleeve expanded to various degrees as pictured in Figure 7 so as to fill the irregularities of the bore 40.

Under still different circumstances as shown in Figures 8 and 9, where comparable irregularities are shown existing in the bore 40 the material of the sleeve 12 may be selected as of a hardness appreciably greater than that of the sheets 31, 32, 33, and 34. The ultimate result in a relationship of this kind is for the sleeve 12 to expand uniformly and, because of it being harder material, the sleeve will not itself deform but will straighten out irregularities in the bore 40 throughout the length of the bore between the surface 35 and surface 36 of the stack.

When somewhat different conditions prevail as for example those illustrated in Figure 10, a sleeve 12 which is relatively soft will deform variously. For example, as there pictured, the layer 31 and layer 34 are assumed to be of titanium and the layers 32 and 33 of aluminium. When the sleeve expands in the manner heretofore described that portion 40' of the bore which extends through the titanium layers will inhibit undue deformation of the sleeve whereas those portions of the bore 40" which extend through the aluminium layers will be less resistant to deformations of the sleeve 12. As a result there will be a tendency for such portions of the bore to expand slightly as the adjacent portion of the sleeve is expanded against them producing, as shown, a somewhat distorted exterior for

the sleeve, which has been exaggerated for this purpose of explanation.

In many applications, a bucking bar is used in the form of invention of Figures 1 and 2 for initial expansion of the sleeve 12 by the shaft 21 of the bolt 11, in lieu of using the nut 13, in which case the head need not include a wrenching means, after which the nut 13 can be applied for permanent installation.

In the form of the invention of Figures 11 to 16 inclusive, a sub-assembly 55 consists of a sleeve 12′ and a bolt 56. In this instance, the bolt has a customary shaft 57 but a rounded countersunk head 58 which provides a secondary taper 59. For the sub-assembly to have the form shown in Figure 11, the bolt is drawn initially partially into a passage 16 of the sleeve 12 sufficient to start a flare 60 at the thin end of the sleeve. A wrench hold like a hexagonal socket 68 in the shaft 57 is of particular advantage. This expedient also lightens the weight.

Under this set of conditions also sheets 61 and 62 are provided with a bore 63 but at the end of the bore 63 in the sheet 62 there is provided a countersink 64 which is substantially, but not completely, complementary to the angle of the taper 59 and flare 60. As shown in Figure 12, the angle Y of the taper 59 is slightly larger than the angle of the countersink 64. In the example shown it can be assumed that the angle X is about 99° and the angle Y is about 102°, making a 3° difference. It is only the difference is angular relationship, however, which is significant in that bolts of this character may have an angle Y at the head of 82°, 70°, 60° etc. depending upon various factors such as the hardness of the material, required bearing amount of countersink desired, amount of rounded protrusion permissible, and other conventional factors.

Further, although an angular difference of 3° has been disclosed, it will be understood that this precise difference in angle is not critical and that slight variations of either greater or less may fit certain circumstances to better advantage where the flare angle differs. The objective under all circumstances is to provide an ultimate interference fit or surface compression between the thin end of the sleeve 12′ at the flare 60 and the countersink 64 in addition to the interference fit between the exterior surface 15′ of the sleeve 12′ and the bore 63.

In the situation portrayed in Figures 11, 12, and 13 for example, the sleeve is assumed to be too long for the length of the bore 63 due to the sheets 61 and 62 being slightly undersize. To accommodate this, a counterbore washer 65 is made use of providing a counterbore 66 for reception of the protruding end of the sleeve 12′. For this same condition, the nut 13′ is made use of which has a counterbore 67 to accommodate the protruding end of the sleeve 12′. The washer may be left in place if desired.

The flare on the sleeve on some occasions may extend to the widest part of the head 58, as would be the case with a sleeve of hard material. The partially formed flare 60 of Figure 11 presumes a more readily formable material.

For special circumstances, as for example where a sealed connection may be requisite, a sleeve 70 of the type shown in Figures 14, 15, and 16 may be preferred. The sleeve there shown has a flared recess 71 at the thick end of the sleeve which makes a smooth transition from the passage 72. An additional expedient resides in providing the countersink 64 with a large dimension head of diameter *b* slightly smaller than the dimension *a* of the largest end of the head 58. This is usually installed with a bucking bar and rivet gun.

For initially drawing the sub-assembly into engagement with the bore 63, a counterbore washer 65 as shown in Figure 15 with the counterbore 66 may be employed. To give the sleeve 70 its final form, a washer 73 is used, this washer may, if desired, have an annular flare (not shown), the purpose of which is to work the thick end of the sleeve 70 outwardly into a flare 75 which overlies a correspondingly flared countersink 76 in the layer 62.

What is of exceptional significance in all forms of the invention is that the shaft is always made of precisely the same taper and diameter. This applies equally well whether it be the shaft of the bolt of Figures 1 to 4 or the shaft of the tapered head bolt of Figures 11 to 16.

When for example it becomes necessary for any reason, whether in the shop or in the field, to replace the fastener originally installed this can be done by first removing the fastener and then replacing it with a new fastener. In actual practice it is invariably necessary after removing the fastener initially installed to ream the hole to an oversize inside diameter. This may be an enlargement of 1/64 inch if it be the first replacement or 1/32 inch if it be the second replacement.

A replacement fitting then must have a sleeve of slightly greater thickness for the first replacement, enough so that the exterior surface has a diameter 1/64 greater than the initially installed sleeve. Precisely the same standard bolt however is usable with the sleeve of greater thickness namely, the replacement sleeve. In other respects the replacement assembly is the same in all

respects as has been described for the initially installed fastener.

When there is to be a second replacement all that is needed is to provide a new second replacement sleeve of even greater thickness namely a thickness sufficient to provide an exterior cylindrical surface which is 1/32 inch greater in diameter than the diameter of the initially installed sleeve, and still use the standard bolt. In the replacement sleeve last described as in the first described replacement sleeve the tapered passage 16 through the sleeve remains of precisely the same size as the passage 16 for example, described in connection with the assembly of Figure 1. Naturally therefore the standard bolt, rivet, or stud fits both replacement sleeves and there need never be employed or stocked any type of bolt, rivet, or stud other than standard. Consequently replacements can readily be made just as well in remote field installations as in the factory itself.

WHAT I CLAIM IS:—

1. A fastener for making a joint with multiple layers of material having a cylindrical hole there-through comprising a shaft having a tapered shank and a hollow cylindrical sleeve of generally constant outside diameter but internally having the same taper as said shank, the maximum internal diameter of the sleeve being less than the maximum diameter of the shank, a portion of said sleeve being arranged to accept and be expanded by an initially inserted portion of the tapered shank such that a remaining portion of the shaft lies within but not contacting a remaining portion of the sleeve, said remaining portion of the sleeve having a wall thickness which is reduced to compensate for expansion of said remaining portion of the sleeve when the shank is fully inserted into the sleeve so that the exterior surface of the sleeve then has a constant outside diameter.

2. A two piece high strength fastener consisting of a partially assembled tapered shaft and internally tapered hollow cylindrical sleeve, the shaft having a tapered shank with a maximum diameter at one end, the hollow cylindrical sleeve having a given outside diameter and a tapered inside diameter defining a maximum diameter at one end that is less than the maximum diameter on said tapered shank, said taper on the said shank being substantially equal to said taper on said sleeve, the sleeve being initially inserted over the tapered shank and positioned at a given distance from said maximum diameter end of the shank with that portion of sleeve contacting said tapered shank being radially expanded, and the outside diameter of the expanded sleeve having been reduced to a given cylindrical dimension, the improvement comprising reducing the wall thickness of that portion of the sleeve remaining un-contacted by the initially inserted shank to compensate for expansion of said remaining portion of the sleeve when the shank is fully inserted into the sleeve so that the exterior surface of the sleeve then has a constant outside diameter.

3. A fastener as claimed in Claim 1 or 2 wherein the external diameter of the portion of said sleeve not contacted by said initially inserted shank is taperingly reduced to provide the necessary compensation when expanded.

4. A fastener as claimed in Claim 1 or 2 wherein the internal diameter of the portion of said sleeve not contacted by said initially inserted shank is increased in diameter by a taper of reverse direction to the taper on the shank to provide the necessary compensation when expanded.

5. A fastener as claimed in any preceding claim wherein the taper of the shank and the sleeve is between 0.15 inch and 0.5 inch per foot.

6. A fastener as claimed in any preceding Claim wherein there is provided a head defining a shoulder formed to said tapered shank by an annular fillet portion.

7. A two piece high strength fastener consisting of a partially assembled shaft and internally tapered hollow cylindrical sleeve, the shaft having a tapered shank with a maximum diameter at one end, the hollow cylindrical sleeve having a given outside diameter and a tapered inside diameter defining a maximum diameter at one end that is less than the maximum diameter on said tapered shank, said taper on said shank being substantially equal to said taper on said sleeve, the sleeve being inserted over the tapered shank and positioned at a given distance from said maximum diameter end of the shank to radially expand that portion of sleeve contacting said shaft, the method of compensating for the unexpanded portion of the sleeve comprising the steps of reducing the outside diameter of the expanded sleeve to a given cylindrical dimension, and further reducing the wall thickness to compensate for expansion of said portion of sleeve not contacted by the shaft in said partial assembly when the shaft is fully inserted into the sleeve so that the sleeve then has a constant outside diameter.

8. A fastener as claimed in claim 7 in which the method includes the step of reducing the external diameter of the portion of the tapered sleeve not contacted by said shaft to provide the necessary compensation when expanded.

9. A fastener as claimed in claim 7 in which the method includes the step of

increasing the internal diameter of the portion of the tapered sleeve not contacted by said shaft to provide the necessary compensation when expanded.

10. A fastener substantially as herein described with reference to, and as illustrated in, Figures 1 to 5, 6 and 7, 8 and 9, 10, 11 to 13, 14 to 16, or 19 of the accompanying drawings.

11. A method of providing compensation in a two piece high strength fastener substantially as herein described with reference to, and as illustrated in, Figures 1 to 5, 6 and 7, 8 and 9, 10, 11 to 13, 14 to 16 or 19 of the accompanying drawings.

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1524866 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1.

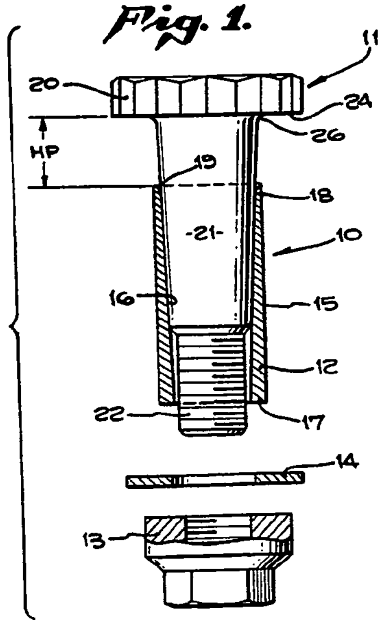



Fig. 2.

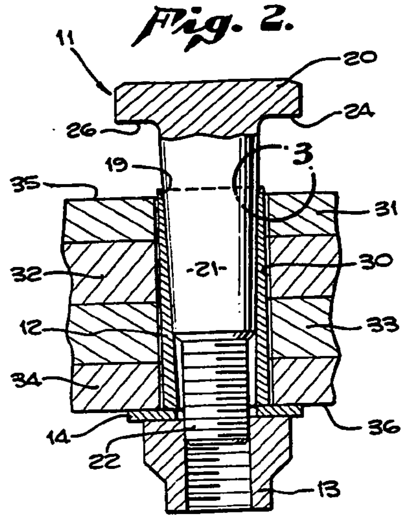



Fig. 3.

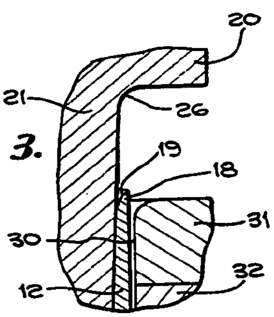



Fig. 4.

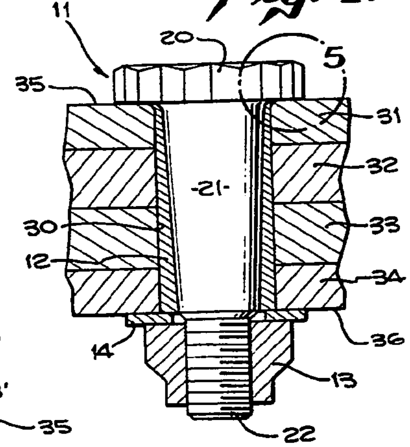



Fig. 5.

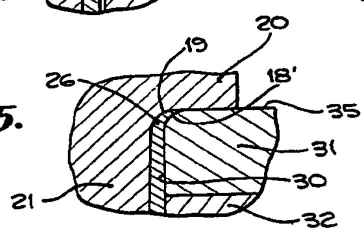


Fig. 6.

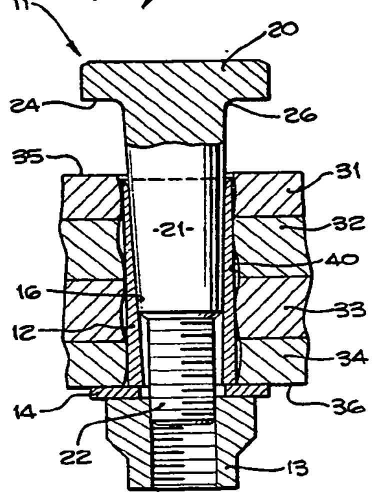
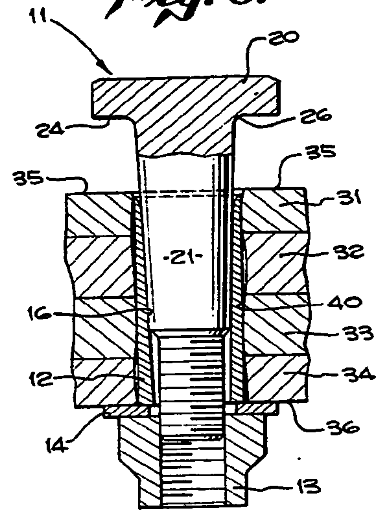



Fig. 8.

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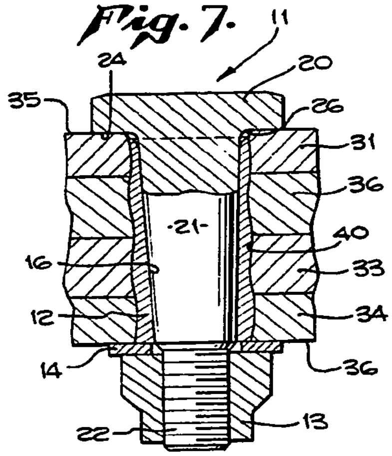


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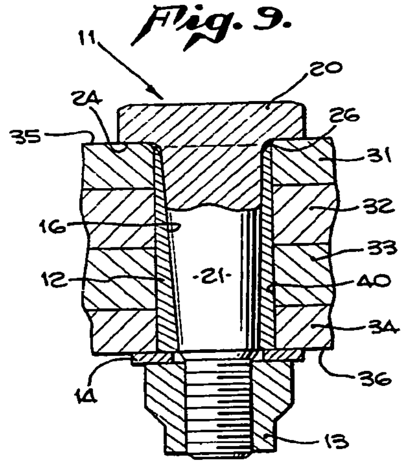

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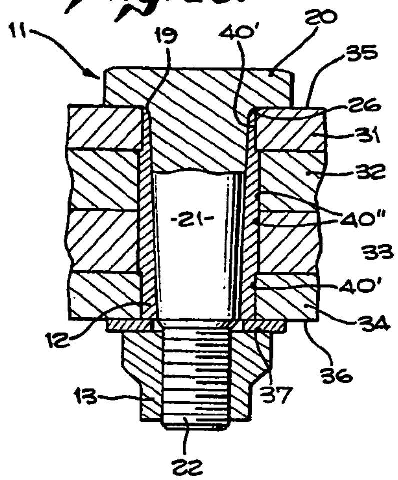
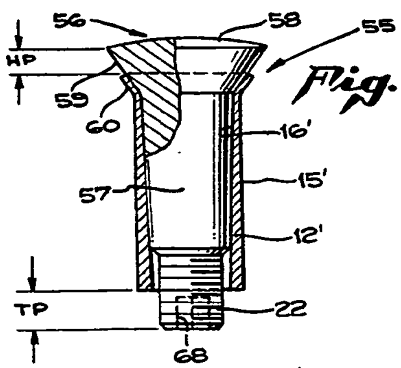


1524866 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

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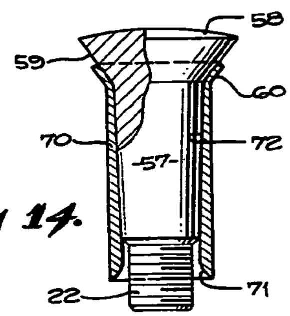



Fig 14.

Fig. 12.

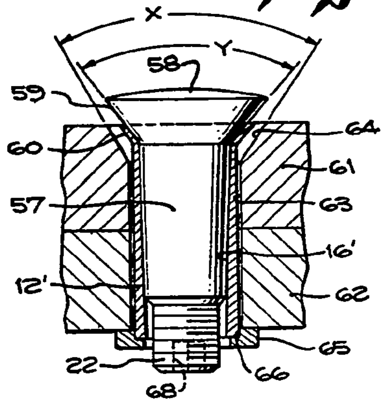
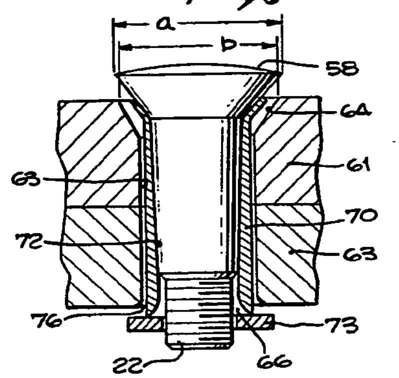



Fig. 15.

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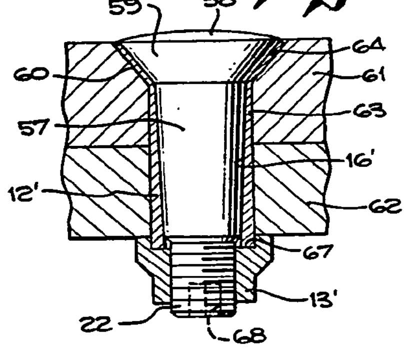


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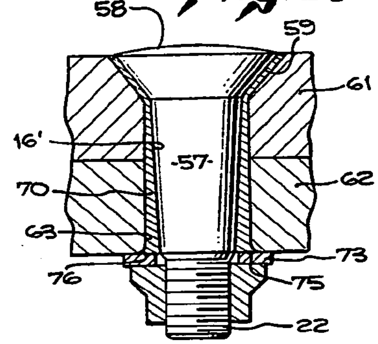

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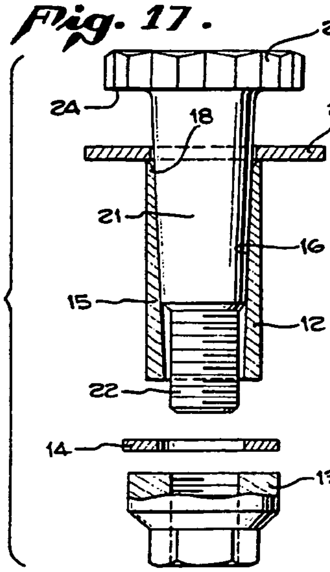


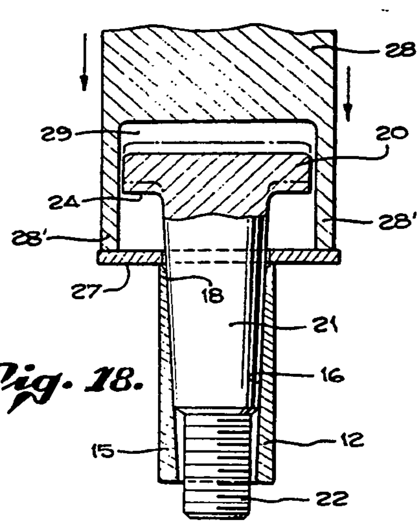


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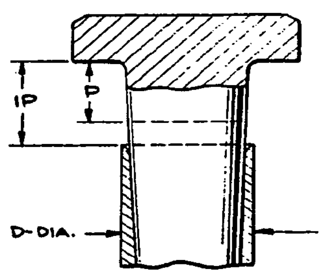


Fig. 19.